INTERPRETING MARTIAN PALEOCLIMATES FROM VALLEY NETWORK MORPHOLOGIES: INSIGHTS FROM TERRESTRIAL ANALOGUES IN EGYPT. K. Nicoll[1,2] and G. Komatsu[3,4], [1]Department of Geosciences, University of Arizona, Tucson AZ 85721, U.S.A.; [2]Chevron Overseas Petroleum Incorporated, 6001 Bollinger Canyon Rd, San Ramon, CA 94583 U.S.A. (nika@chevron.com); [3]International Research School of Planetary Sciences, Universita' d'Annunzio, Viale Pindaro 42, 65127 Pescara, Italy (goro@sci.unich.it); [4]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA.

Morphogenetic classification of Martian landforms has provided a context for the inference of surface processes and paleoclimatic conditions on Mars [1][2][3][4][5][6]. The complexity of extensive valley network patterns (Figure 1) suggests that fluvial conditions formerly existed on Mars [7]; however, surface reworking and the lack of absolute age control complicates the precise definition of this time period.

We summarize and review this literature in the context of analogous terrestrial settings where detailed field studies and chronostratigraphic data are available. Extensive linear drainage patterns such as Wadi Mareef in southern Egypt (Figures 2 and 3) are similar to some type of valley networks on Mars such as Nirgal Vallis (Figure 4). The morphological characteristics of drainage pattern and density of Wadi Mareef and Nirgal Vallis are strongly similar. Field study indicates that Wadi Mareef was a spring-fed stream which intermittently flowed during the Cenozoic, which was dominantly an arid time period [8][9]. Along Wadi Mareef, carbonates were precipitated via discharge of an ambient waters emerging from springs [10]. Petrographic examination of prepared thin sections reveals no clear textural evidence for a hydrothermal origin of the carbonate rocks, suggesting a shallow meteoric origin of the fossil-spring waters. Sapping and fluvial dissection processes played roles in the geomorphic evolution of the drainage networks in Egypt [11]. Radiometric dates from the region suggest that the episodic streamflow was modulated by abrupt hydroclimatic variations which can be linked to variations of the Earth's orbital cycle of 100 ka [12][13].

Though the Egyptian landscape has been dominantly hyperarid over the past 2 million years [14], the region of Wadi Mareef has effectively preserved the geomorphic evidence of rare rainfall and streamflow events. Without the benefit of surface studies and isotopic dates, a casual interpretation of the aggregate surface morphologies would suggest a predominantly wet climate. This terrestrial example illustrates that drainage networks are aggregate features or palimpsests which may evolve over many time scales. Moreover, landscape features may be genetically and climatically non-specific. Hence, paleoclimatic inferences from valley network patterns may be oversimplified. It is essential to view landscape features through the vantage of equifinality: features may evolve through a number of pathways as a nonlinear function of multivariate processes over many time scales, from the episodic-catastrophic to the aggregate. In general, the main controls on long-term landscape development on Mars are similar to those observed in terrestrial arid lands: primarily relief and exhumation, with lithology and rock structures exerting secondary controls on landscape evolution. The availability of water controls the rate and style of erosion and landform development. The influence of local controls is apparent in the juxtaposition of drainage patterns with differing degrees of development and complexity.

References:

[1] Maxwell,T.A. (1981) In Annals of the Geological Survey of Egypt, 11, 281-300. [2] Maxwell, T.A. and El Baz, F. (1981) In Annals of the Geological Survey of Egypt, 11, 247-259. [3] McCauley, J.F. et al. (1981) In Annals of the Geological Survey of Egypt, 11, 207-239. [4] Baker, V.R. (1982) The Channels of Mars. [5] Carr, M.H. (1987) Nature, 326, 30-35. [6] Gulick, V.C. and Baker, V.R. (1989) Nature, 341, 514-516. [7] Craddock, R.A. et al. (1998) LPSC. [8] Kropelin, S. (1993) Catena Supplement, 26, 31-65. [9] Van Zinderren Bakker, E.M. and Mercer, J.H. (1986), Palaeogeography, Palaeoclimatology, Palaeoecology 56, 217-235. [10] Nicoll, K. (1997), M.A. thesis, 145 p. [11] Luo, W. et al. (1997) GSA Bulletin, 109, 43-62 [12] Clemens, S.C. and Tiedemann, R. (1997) Nature, 385, 801-804. [13] McHugh, W.P. et al. (1988) Journal of Field Archaeology, 15, 361-379. [14] Nicoll, K. (1998) Ph.D dissertation, 290 p.

Figure 1. Mars Global Surveyer image of drainage pattern in Nanedi Vallis.

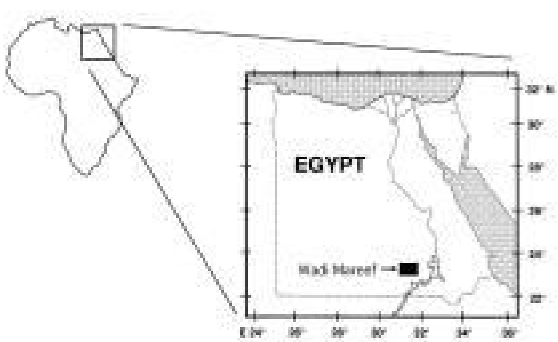

Figure 2. Geographic location of Wadi Mareef, southern Egypt (23-24°N, 31-32°E).

Figure 3. Landsat MSS image of Wadi Mareef. The frame width is about 55km.

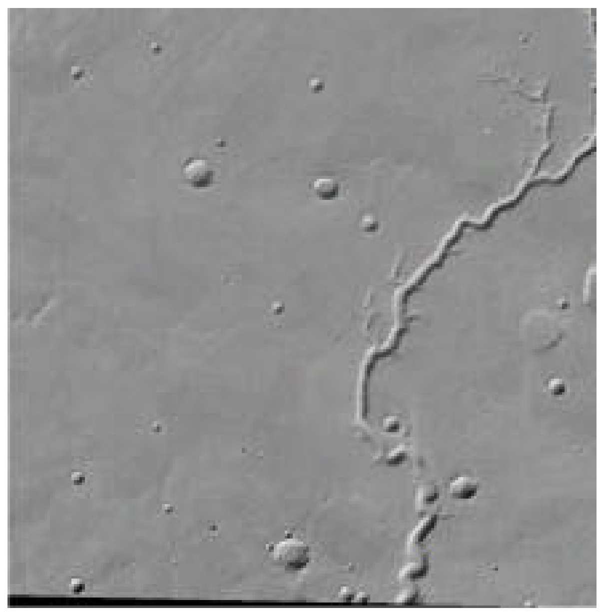

Figure 4. Viking image of Nirgal Vallis, Mars. The frame width is about 180km.